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EAR FALLS GS
EVALUATION OF CONCRETE CORES

Report No 89-160-K

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ABSTRACT

The concrete portions of six cores drilled through the Ear Falls GS powerhouse into bedrock were evaluated. The cores were found to represent three different types of concrete, probably corresponding to different periods of construction of the station. Although the cores were retrieved in short sections, a borehole camera survey did not reveal extensive cracking of the concrete. A petrographic examination of polished and thin sections revealed that the majority of the aggregate is not reactive; however, reactive chert, making up less than 2% of the aggregate, is present.

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EAR FALLS GS
EVALUATION OF CONCRETE CORES

E.J. McColm

1.0 INTRODUCTION

In November, 1988, concrete cores, including sections of foundation bedrock, were drilled from six selected locations of the Ear Falls GS powerhouse as part of a SHARP investigation. The drilling was conducted by a contractor under the supervision of the Rock Science Section, Civil Research Department. An evaluation of the concrete portion of these cores was made by the Concrete Technology Section, Civil Research Department, and is reported here. The bedrock and concrete-rock interface will be assessed by others.

The concrete evaluation consisted of a visual examination of the cores, including a microscopic examination of polished and thin sections, and the review of a limited borehole camera survey. Physical testing of the concrete was not carried out because of the small diameter of the cores (nominal 45 and 60 mm).

A proposed program, to inspect and obtain concrete core specimens from the scroll case and draft tube areas, could not be undertaken because of restricted access caused by high water levels. Specimens from selected locations of this station were, however, obtained and evaluated during an earlier testing program conducted in August 1988 and reported[/1/] in March 1989.

2.0 OBSERVATION AND DISCUSSION

The locations of the six boreholes, drilled in the powerhouse, are shown in Figure 1. The cores, as received in the Civil Research Department laboratory, are shown in Figures 2 to 7. A concrete core log is given in Appendix A.

The cores represent three different types of concrete. Each of the station's four units was constructed separately over approximately 20 years (unit in-service dates 1930-1948), which probably accounts for the different concretes.

/1/ "Ear Falls GS, Concrete Condition Survey", Ontario Hydro Research Report 88-289-K, March 20, 1989

2.1 Cores 1, 2 and 6

The concrete in Cores 1, 2 and 6 (Figures 2, 3 and 7) is probably the oldest, based on the location of the boreholes in the vicinity of Unit 1 (in-service 1930).

The cores are generally broken into short lengths. The ends of many core sections were ground during drilling which made it difficult to differentiate between breaks caused by drilling, construction joints and cracks in the concrete. The breaks that could be inspected occur primarily in the mortar phase. Near the top of the cores, breaks through aggregate particles were also noted. The review of the limited borehole camera survey did not identify extensive cracking of the concrete.

The coarse aggregate appears to have originated from crushed rock, possibly from the bedrock, and is poorly graded and distributed throughout the concrete. In particular, there is a predominance of large size coarse aggregates in some locations, while other areas contain only mortar. Flat and elongated particles are also present. The nominal maximum size of the aggregate is 40 mm, including some 50 mm pieces.

The concrete contains numerous voids and sections of honeycombing. Some voids contain a white deposit, especially in sections near the top of the cores. Reaction rims were noted around a few of the aggregate particles.

A microscopic evaluation of the concrete, using polished and thin sections, is reported in Appendix B. The concrete was found to be non-air-entrained, with some voids filled or partially filled with alkali-aggregate reaction products. Microcracking, extending through some coarse aggregate particles and into the mortar, was also noted. Further examination using thin sections determined that most of the aggregate particles do not appear to be reactive. The cracking and presence of reaction products are attributed to the presence of reactive chert particles that make up less than 2% of the total aggregate. The distress due to the alkali-aggregate reactivity appears to be localized and may have minor effect on the overall integrity of the concrete.

2.2 Cores 3 and 4

Cores 3 and 4 (Figures 4 and 5) were drilled to the east and west of Unit 3 and appear to consist of similar concrete as that reported above. The differences consist of better aggregate distribution in Cores 3 and 4, although some localized sections primarily contain mortar, and a lower incidence of white deposits in voids and reaction rims around the aggregates.

2.3 Core 5

The concrete in Core 5 (Figure 6) is probably the most recent since the borehole is located east of Unit 4 (in-service 1948), the last unit constructed.

The length of the core sections and the nature of the core breaks were similar to those of Cores 1 and 6. The coarse aggregate is of a different parent material from that of the other cores and was obtained from a gravel deposit.

The aggregate grading and distribution are good, with a nominal maximum size of 28 mm, including a few larger 40 mm pieces. The review of the limited borehole camera survey did not identify extensive cracking of the concrete.

Although voids and honeycomb sections are present in the core, the occurrence of white deposits was much less than that in the other cores. Reaction rims around aggregate particles were not noted.

The microscopic examination of a polished specimen, reported in Appendix B, revealed that the concrete is not air-entrained. Since no microcracking or reaction products were noted, further investigation using thin sections was not conducted.

3.0 SUMMARY

Three types of concrete were evaluated, probably representing three different periods of construction of the station. The cores were generally broken into short sections which may have been caused by the drilling or as a result of cracks in the concrete, although the limited borehole camera survey did not identify extensive cracking.

The microscopic examination of polished and thin sections revealed that a majority of the aggregate is not reactive; however, the presence of reactive chert, making up less than 2% of the total aggregate, has caused microcracking through some aggregate particles and the mortar at localized areas.

A detailed investigation, including the retrieval and testing of specimens, is required to ascertain the physical properties and quality of the concrete in order to assess its long-term performance.

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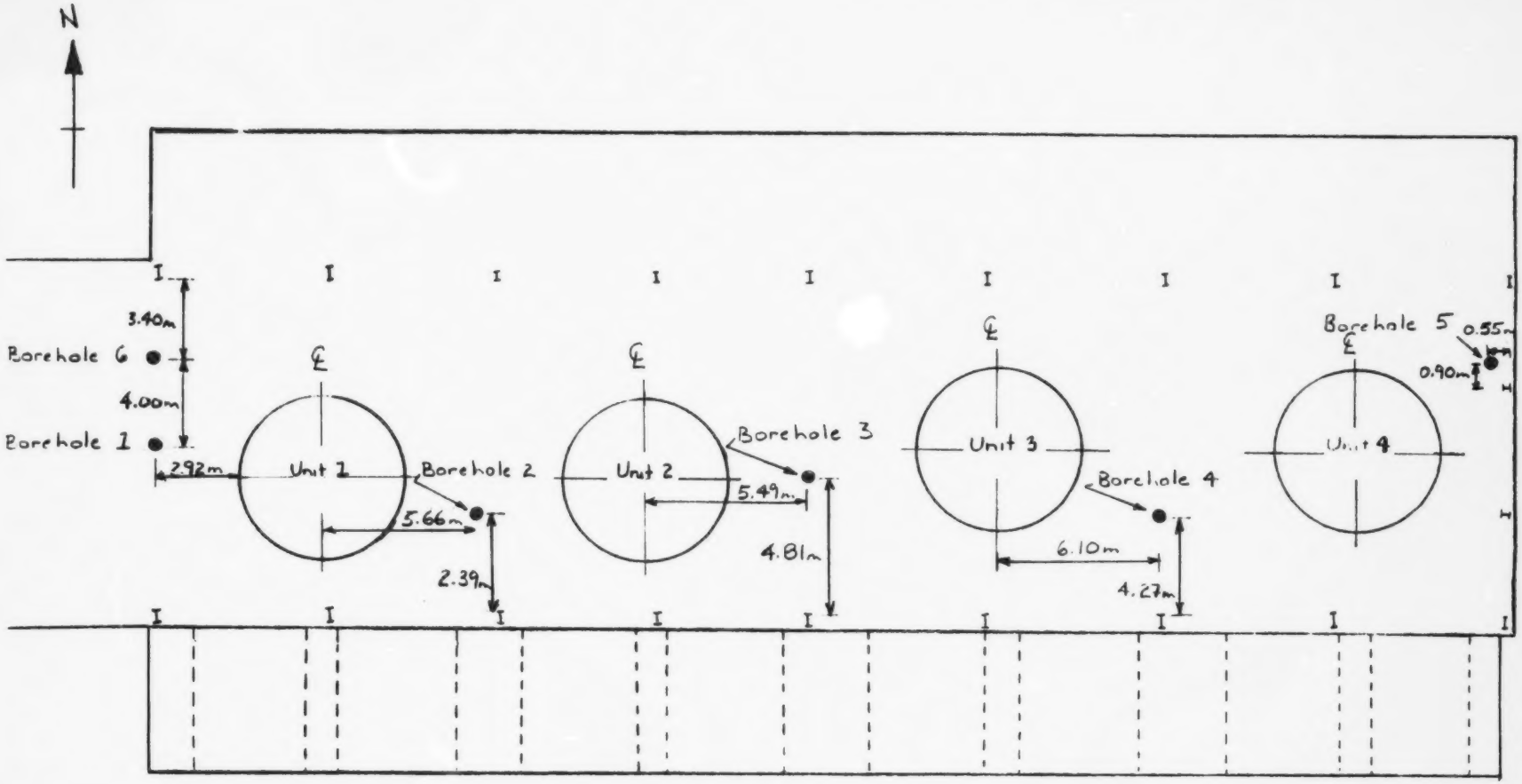

FIGURE 1

Ear Falls GS - Powerhouse
Location of Boreholes

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Figure 2 Core 1 as received in the Civil Research laboratory (nominal 45 mm diameter)

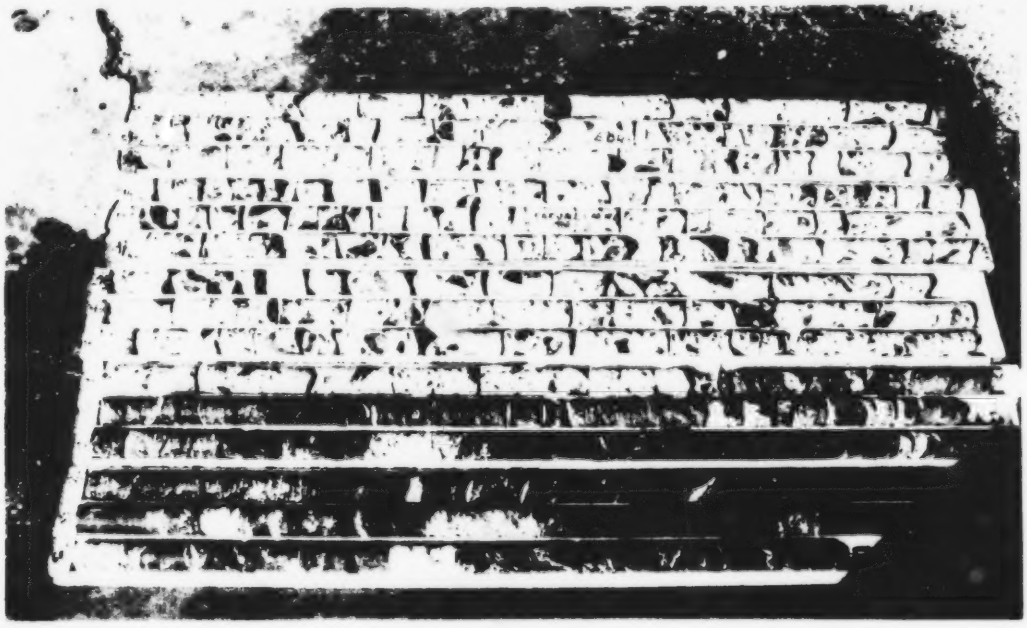

Figure 3 Core 2 as received in the Civil Research laboratory (nominal 45 mm diameter)

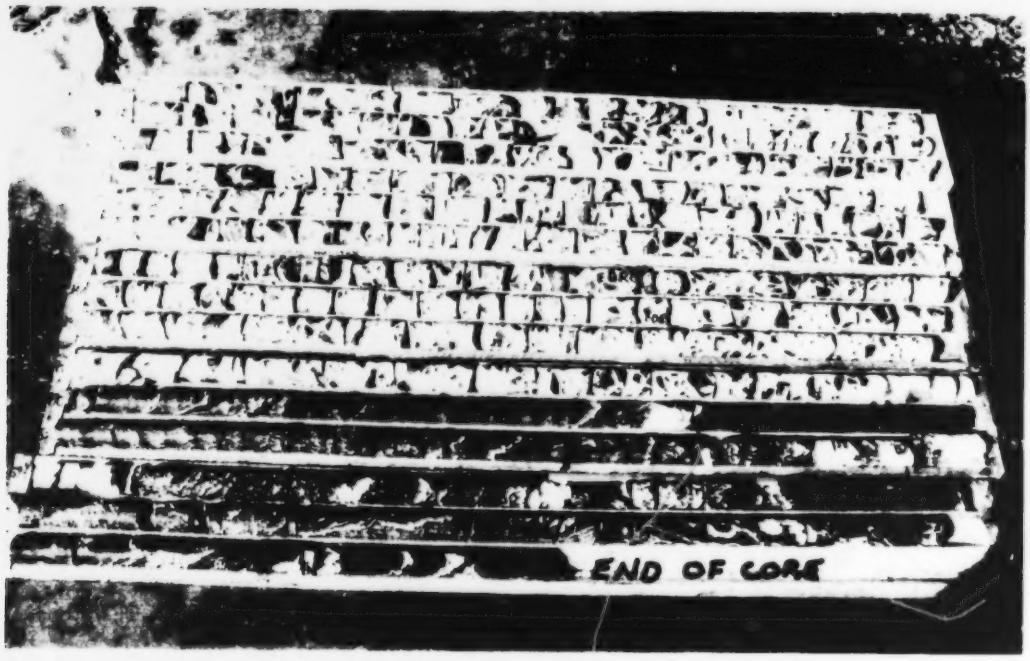

Figure 4 Core 3 as received in the Civil Research laboratory (nominal 45 mm diameter)

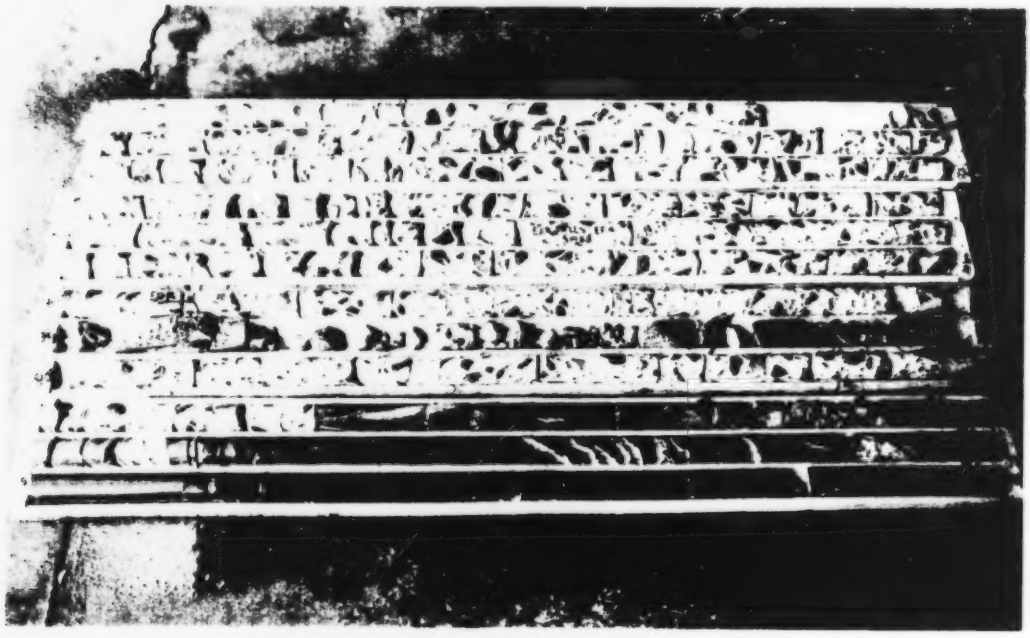

Figure 5 Core 4 as received in the Civil Research laboratory (nominal 45 mm diameter)

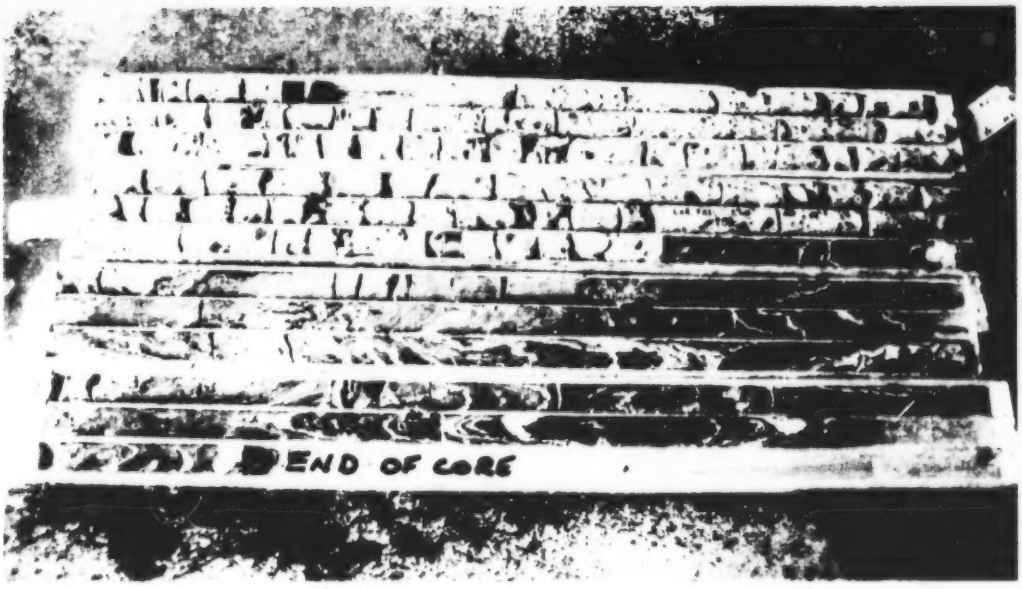

Figure 6 Core 5 as received in the Civil Research laboratory (nominal 45 mm diameter)

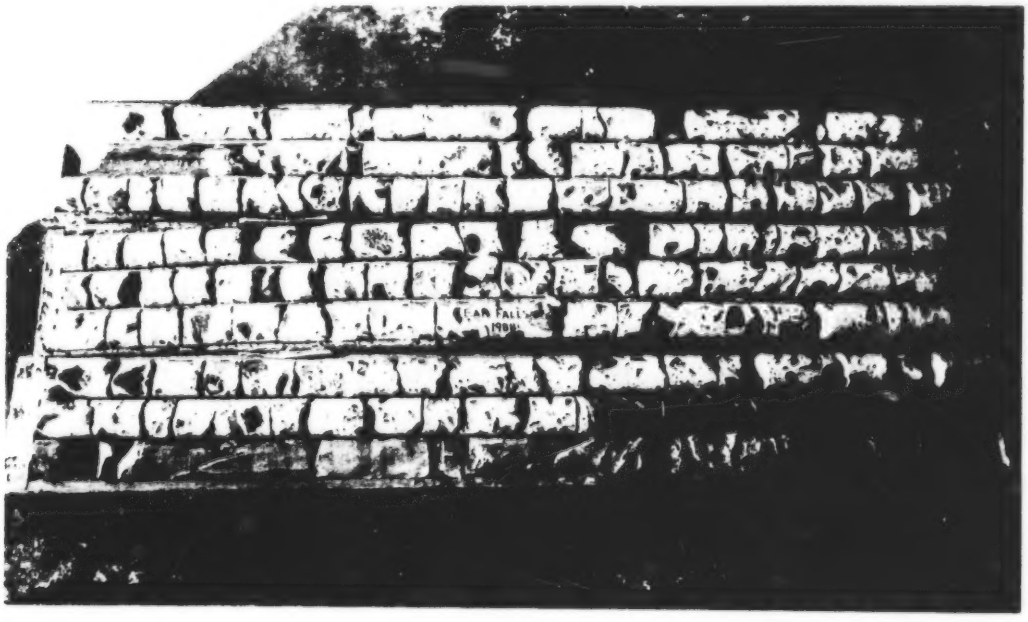

Figure 7 Core 6 as received in the Civil Research laboratory (nominal 60 mm diameter)

Appendix A

EAR FALLS GS
CONCRETE CORE LOG

EAR FALLS GS

CONCRETE CORE LOG

CORE NO.	LOCATION IN CORE (m)	REMARKS
1	0 - 2.13	- Core retrieved in sections, generally 150 to 330 mm long
	2.13	- Steel bar 25 mm diameter
	2.13 - 4.27	- Core retrieved in sections, generally 50 to 200 mm long
	4.27 - 8.84	- Core retrieved in sections, generally 80 to 180 mm long
	4.60	- Steel bar 25 mm diameter
	8.84 - 11.38	- Core retrieved in sections, generally 80 to 180 mm long
	11.38	- Interface between concrete and bedrock

General Remarks

- See Figure 1 for core location and Figure 2 for photo of core.
- Concrete similar to that of Cores 2 and 6.
- Concrete contains numerous voids, including sections of honeycombing.
- Some voids, mainly near the top of the core, contain white deposits.
- Aggregates do not exhibit evidence of extensive alkali-aggregate reactions (ie, reaction rims are in localized areas only).
- Coarse aggregate appears to be crushed rock of nominal maximum size 40 mm, including a few 50 mm pieces.
- Coarse aggregate distribution and grading are poor (ie, general lack of smaller fractions of coarse aggregate particles with the majority of pieces being large).
- A number of elongated coarse aggregate particles are present.
- Breaks in core generally occurred in the mortar.
- Ends of many core sections were ground during drilling.
- No borehole camera survey was conducted.

EAR FALLS GS
CONCRETE CORE LOG

CORE NO.	LOCATION IN CORE (m)	REMARKS
2	0 - 1.35	- Core retrieved in sections, generally 100 to 280 mm long
	1.35 - 2.06	- Core retrieved in sections, generally 50 to 200 mm long
	2.06 - 2.41	- Sound core section
	2.41 - 14.50	- Core retrieved in sections from rubble to 150 mm long
	3.63	- Steel plate
	3.70	- Possible construction joint
	4.83	- Steel bar
	5.03	- Steel plate
	6.60	- Crack
	14.50	- Contact between concrete and bedrock

General Remarks

- See Figure 1 for core location and Figure 3 for photo of core.
- Concrete similar to that of Cores 1 and 6.
- Concrete contains numerous voids, including sections of honeycombing.
- Some voids, mainly near the top of the core, contain white deposits.
- Aggregates do not exhibit evidence of extensive alkali-aggregate reactions (ie, reaction rims are in localized areas only).
- Coarse aggregate appears to be crushed rock of nominal maximum size 40 mm, including a few 50 mm pieces.
- Coarse aggregate distribution and grading are poor (ie, general lack of smaller fractions of coarse aggregate particles with the majority of pieces being large).
- A number of elongated coarse aggregate particles are present.
- Breaks in core generally occurred in the mortar.
- Ends of many core sections were ground during drilling.
- A limited borehole camera survey was conducted.

EAR FALLS GS
CONCRETE CORE LOG

CORE NO.	LOCATION IN CORE (m)	REMARKS
3	0 - 0.81	- Core retrieved in sections, generally 100 to 175 mm long
	0.81 - 1.17	- Core retrieved in sections from rubble to 50 mm long
	1.17 - 1.45	- Sound section of core
	1.45 - 4.27	- Core retrieved in sections, generally 25 to 150 mm long
	1.70	- Steel bar 13 mm diameter
	4.27 - 14.95	- Core retrieved in sections, generally 25 to 100 mm long
	4.50	- Steel bar 13 mm diameter
	4.90	- Steel bar 25 mm diameter
	5.15	- Possible construction joint
	6.00	- Steel bar 25 mm diameter
	11.50	- Possible construction joint
	14.95	- Contact between concrete and bedrock

General Remarks

- See Figure 1 for core location and Figure 4 for photo of core.
- Concrete similar to that of Core 4.
- Concrete contains numerous voids, including sections of honeycombing.
- Some voids contain white deposits and a few reaction rims were noted around the coarse aggregate.
- Coarse aggregate appears to be crushed rock of nominal maximum size 40 mm, including a few 50 mm pieces.
- Coarse aggregate is poorly graded, although the distribution is generally good throughout most of the core.
- A number of elongated coarse aggregate particles are present.
- Near the top of the core, breaks occurred equally through the mortar and the coarse aggregate particles; however, below about 2.0 m, the breaks occurred primarily through the mortar.
- Ends of many core sections were ground during drilling.
- A limited borehole camera survey was conducted.

EAR FALLS GS
CONCRETE CORE LOG

CORE NO.	LOCATION IN CORE (m)	REMARKS
4	0 - 0.53	- Core retrieved in sections, generally 25 to 100 mm long
	0.53 - 1.00	- Sound concrete
	0.60	- Crack
	1.00 - 1.15	- Core retrieved in sections, generally 25 to 100 mm long
	1.15 - 1.42	- Sound concrete
	1.42	- Steel bar 38 mm diameter
	1.42 - 5.05	- Core retrieved in sections, generally 25 to 100 mm long
	2.80	- Steel bar 13 mm diameter
	3.40	- Possible crack
	3.50	- Steel bar 38 mm diameter
	4.10	- Zone of poor quality concrete
	4.60	- Crack
	5.05 - 5.20	- Core retrieved as rubble
	5.20 - 6.85	- Core retrieved in sections, generally 25 to 150 mm long
	6.85 - 7.20	- Core retrieved in sections, generally 200 to 250 mm long
	7.20 - 8.30	- Core retrieved in sections, generally 75 to 100 mm long
	8.26	- Crack
	8.30 - 10.55	- Core retrieved in sections, generally 75 to 200 mm long
	10.55 - 12.50	- Core retrieved as rubble
	10.65 - 11.45	- Rock
	11.45 - 11.90	- Concrete
	11.90 - 12.50	- Rock
	12.50 - 14.40	- Concrete retrieved in sections, generally 100 to 200 mm long
	14.40	- Contact between concrete and bedrock

General Remarks

- See Figure 1 for core location and Figure 5 for photo of core.
- Concrete similar to that of Core 3.
- Concrete contains numerous voids, including sections of honeycombing.
- Some voids contain white deposits and a few reaction rims were noted around some of the coarse aggregate particles.
- Coarse aggregate appears to be crushed rock of nominal maximum size 40 mm, including a few 50 mm pieces.
- Coarse aggregate is poorly graded, although the distribution is generally good throughout most of the core.
- A number of elongated coarse aggregate particles are present.
- Near the top of the core, breaks occurred equally through the mortar and the coarse aggregate particles; however, below about 2.0 m, the breaks occurred primarily through the mortar.
- Ends of many core sections were ground during drilling.
- A limited borehole camera survey was conducted.

EAR FALLS GS
CONCRETE CORE LOG

CORE NO.	LOCATION IN CORE (m)	REMARKS
5	0 - 0.30	- Core retrieved in sections, generally 25 to 75 mm long
	0.10	- Steel plate
	0.30	- Steel bar 25 mm diameter
	0.30 - 1.50	- Core retrieved in sections, generally 100 to 200 mm long
	1.80	- Steel bar 25 mm diameter
	1.95	- Steel bar 38 mm diameter
	2.60	- Crack
	1.50 - 3.75	- Core retrieved in sections from rubble to 175 mm long
	3.70	- Steel bar 13 mm diameter
	3.75 - 3.95	- Core retrieved as rubble
	3.95 - 7.00	- Core retrieved in sections from rubble to 175 mm long
	4.40	- Steel bar 13 mm diameter
	5.10	- Steel bar 13 mm diameter horizontal crack at bar
	5.85	- Steel bar 38 mm diameter
	6.20	- Steel bar 38 mm diameter
	6.50	- Steel bar 13 mm diameter
	6.85	- Steel Bar 38 mm diameter
	7.00 - 8.55	- Core retrieved in sections from rubble to 100 mm long
	8.20	- Steel bar 38 mm diameter
	8.4	- Crack
	8.55	- Contact between concrete and bedrock

General Remarks

- See Figure 1 for core location and Figure 6 for photo of core.
- Concrete contains numerous voids, including sections of honeycombing.
- Fewer white deposits were noted in the voids than in the other cores.
- No reaction rims were observed around aggregate particles.
- Coarse aggregate appears to be from a gravel deposit, with a nominal maximum size of 28 mm, including a few 40 mm pieces.
- Most breaks occurred through the mortar.
- A limited borehole camera survey was conducted.

EAR FALLS GS
CONCRETE CORE LOG

CORE NO.	LOCATION IN CORE (m)	REMARKS
6	0 - 2.13	- Core retrieved in sections, generally 100 to 400 mm long
	1.00	- Steel bar 38 mm diameter
	1.22	- Steel bar 38 mm diameter
	1.73	- Steel bar
	1.93	- Steel bar 25 mm diameter
	2.13 - 10.87	- Core retrieved in sections, generally 50 to 100 mm long
	10.87	- Contact between concrete and bedrock

General Remarks

- See Figure 1 for core location and Figure 7 for photo of core.
- Concrete similar to that of Cores 1 and 2.
- Concrete contains numerous voids, including sections of honeycombing.
- Some voids, mainly near the top of core, contain white deposits.
- Aggregates do not exhibit evidence of extensive alkali-aggregate reactions (ie, reaction rims in localized areas only).
- Coarse aggregate appears to be crushed rock of nominal maximum size 40 mm including a few 50 mm pieces.
- Coarse aggregate distribution and grading are poor (ie, general lack of smaller fractions of coarse aggregate particles with the majority of pieces being large).
- A number of elongated coarse aggregate particles are present.
- Breaks in core generally occurred in the mortar.
- Ends of many core sections were ground during drilling.
- A limited borehole camera survey was conducted.

Appendix B

EAR FALLS GS
PETROGRAPHIC EXAMINATION OF CONCRETE CORES

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To: Dr. T.W. Klym
Manager
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Attn: Mr. E.J. McColm

EAR FALLS GS
PETROGRAPHIC EXAMINATION OF CONCRETE CORES

M.F. Everitt

1.0 INTRODUCTION

As part of a program undertaken by the Civil Research Department to investigate the quality of the concrete at Ear Falls GS, core specimens taken from the powerhouse were examined petrographically. This study is supplementary to Report No. 89-160-K which contains details on the drilling program, location of cores and core logs.

2.0 OBSERVATIONS

A visual assessment of the cores indicated two different types of concrete from a petrographic standpoint. Representative specimens of each type of concrete were selected for detailed microscopic observations.

Core 5 contains crushed gravel as coarse aggregate and represents concrete from Unit 4. Cores 4 and 6 contain crushed bedrock as coarse aggregate and represent concrete from Units 1 to 3.

A detailed petrographic examination of hardened concrete for each core is included in Attachments 1 to 3. A summary of the results of a visual assessment of the cores coupled with a stereoscopic examination (magnification up to 80X) and a thin section analysis, where required, is given below.

2.1 Core 5

2.1.1 Visual and Stereoscopic Examination

The concrete consists of natural, sub-rounded to sub-angular (nominal size = 28 mm), granite gneiss coarse aggregate, with minor amounts of greywacke and argillite, evenly distributed and randomly oriented in a dull, light grey, non-air-entrained cement paste.

The fine aggregate is sub-rounded to sub-angular granite gneiss, quartz and feldspar. Construction records show that both fine and coarse aggregates were supplied by the Bergmann Construction Company from a natural deposit (Bergmann's Pit), located 3-1/2 miles south-east of Ear Falls.

Entrapped air voids are irregularly shaped, having a maximum dimension of less than 15 mm. Void interiors have a dull lustre and lack any mineralization. No cracking was observed in the paste.

2.1.2 Thin Section Analysis

Due to the absence of cracking and reaction products, further analysis using thin sections was not conducted.

2.2 Cores 4 and 6

2.2.1 Visual and Stereoscopic Examination

The concrete consists of crushed, angular to sub-angular, biotite garnet gneiss (nominal size = 40 mm) coarse aggregate, unevenly distributed and randomly oriented in a dull, light grey, non-air-entrained cement paste. Some sections contain a concentration of large aggregates, while others contain only mortar. The fine aggregate consists of angular quartz and feldspar grains and flakes of biotite. Minor amounts of chert, argillite and volcanics are also present. Entrapped air voids are irregularly shaped, and some of these voids are either partly lined or totally filled with portlandite, ettringite and/or alkali-silica gel.

Microcracks extending through some coarse aggregate particles and into the cement paste were noted. Thin sections of both cores were prepared to investigate the extent of alkali-silica reactions.

2.2.2 Thin Section Analysis

In plane transmitted light, the cement paste is blotchy, consisting of pale tan matter indicative of normal cement hydration (see Figure 1) grading to a dark brown to black gel soaked paste (see Figure 2). The paste contains numerous relict unhydrated cement grains which may be bordered by gel. In isolated incidents, unhydrated cement clinker has formed agglomerates up to 5 mm in diameter (see Figure 3). These cement clusters do not appear to have caused any distress within the concrete.

In general, borders of coarse aggregate particles appear sound, showing no evidence of deleterious interaction with the cement paste (see Figure 4). Rosettes of ettringite occupy bleed-water voids along the periphery of coarse aggregate particles (see Figure 5) and entrapped air voids within the paste. This is a natural phenomenon and is expected in normal Portland cement concrete over 2 or 3 years old.

Microcracking observed in polished specimens appears to be due to the presence of reactive chert particles which make up less than 2% of the total aggregate. These particles, where present, have partially or completely gelatinized, with gel extending into the cement paste along microcracks (see Figures 6(a) and (b)).

3.0 REMARKS

a) The coarse aggregate used in Unit 4 concrete appears to be non-reactive with the cement paste under in-situ conditions. Presence of potentially expansive alkali-silica gel was not noted. Microcracking was not observed.

b) Greater than 95% of the coarse aggregate used in concrete for Units 1 to 3 shows no sign of alkali-aggregate reactivity. The presence of less than 2% reactive chert has caused microcracking within the concrete. These particles have gelatinized to varying degrees, with gel extending along microcracks into the paste.

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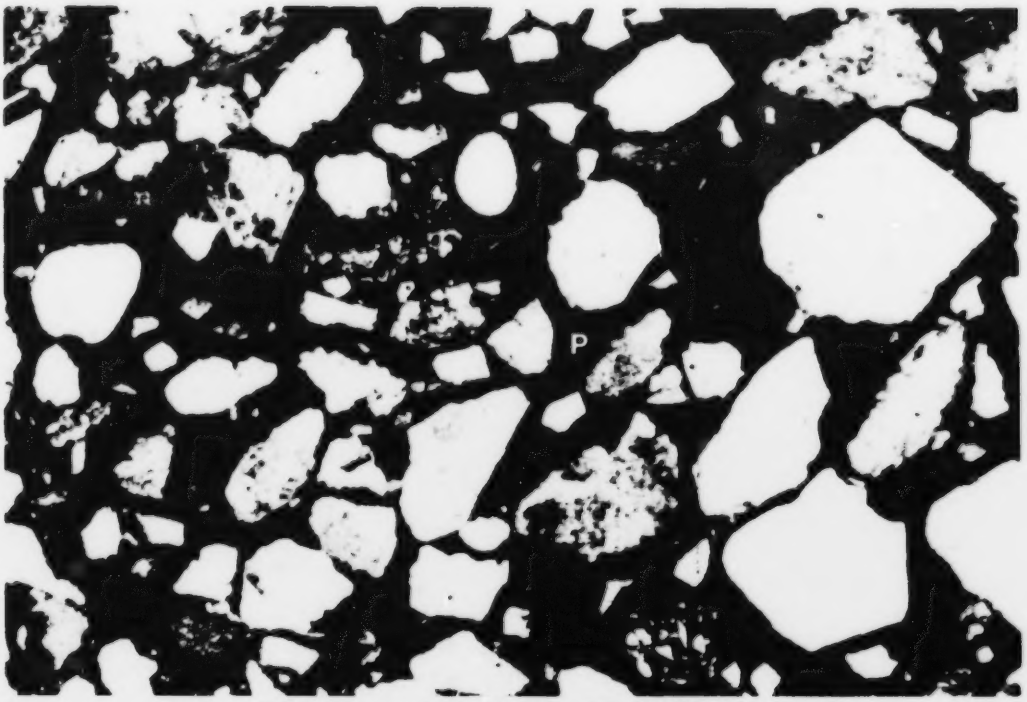


FIGURE 1 - EAR FALLS GS, CORE 4
Tan coloured normal hydrated cement paste (P) with sub-angular quartz/feldspar grains. (Mag. 10.2X, Analyzer out)

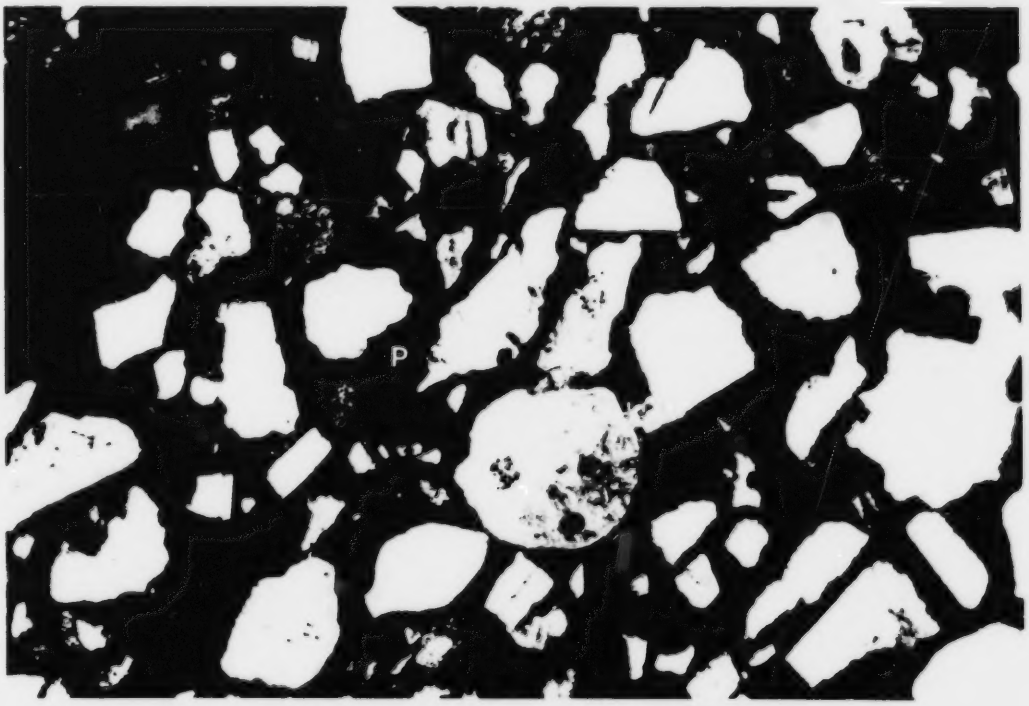


FIGURE 2 - EAR FALLS GS, CORE 4
Microphotograph showing dark gel soaked paste (P) using same light intensity as Figure 1.
(Mag. 10.2X, Analyzer out)

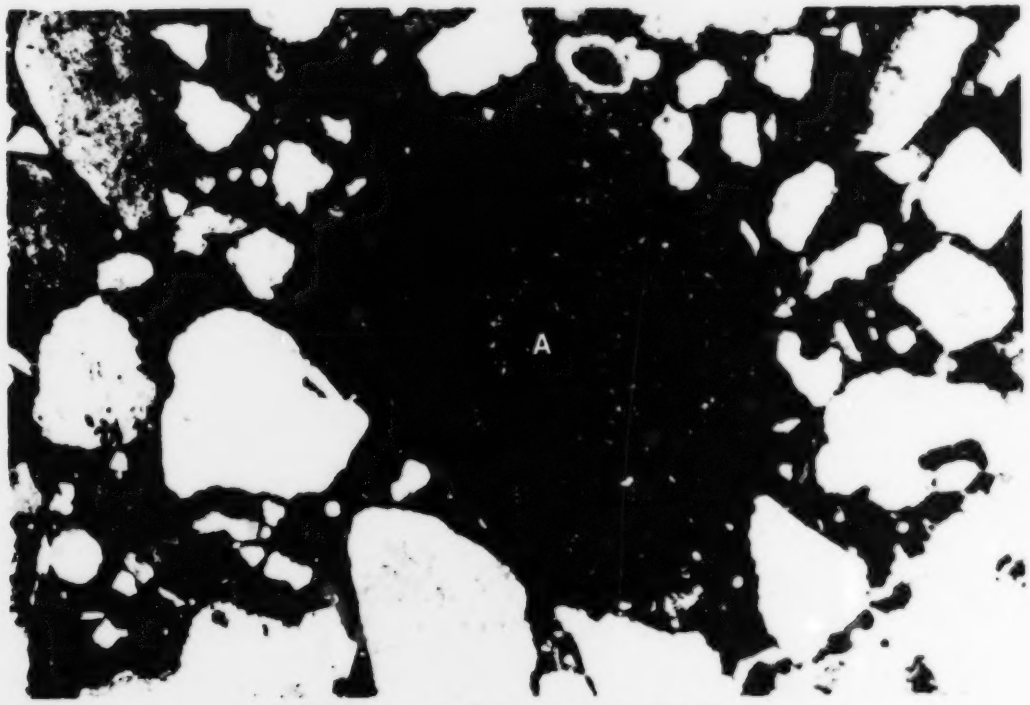


FIGURE 3 - EAR FALLS GS, CORE 6
Agglomerate of unhydrated cement grains (A)
(Mag. 10.2X, Analyzer out)

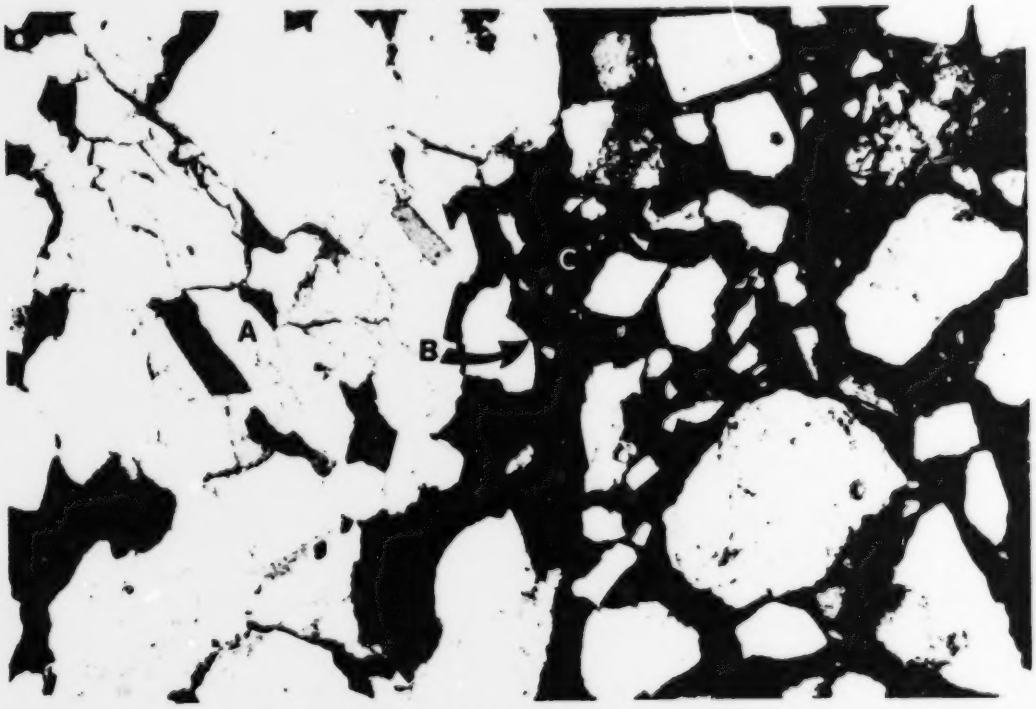


FIGURE 4 - EAR FALLS GS, CORE 6
Microphotograph illustrating unreactive boundary (B)
between cement paste (C) and biotite garnet gneiss coarse aggregate (A)
(Mag. 10.2X, Analyzer out)

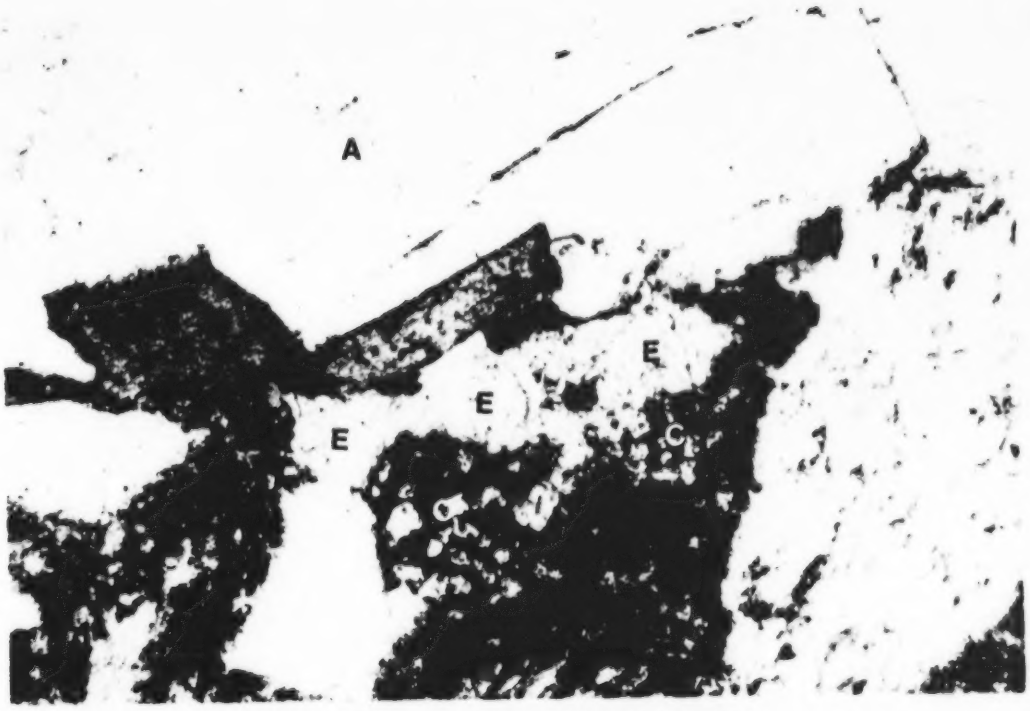


FIGURE 5 - EAR FALLS GS, CORE 6
Rosettes of ettringite (E) occupying a bleed-water
void below a biotite garnet gneiss coarse aggregate (A).
Note the presence of two grains of unhydrated cement clinker (C).
(Mag. 41X, Analyzer out)

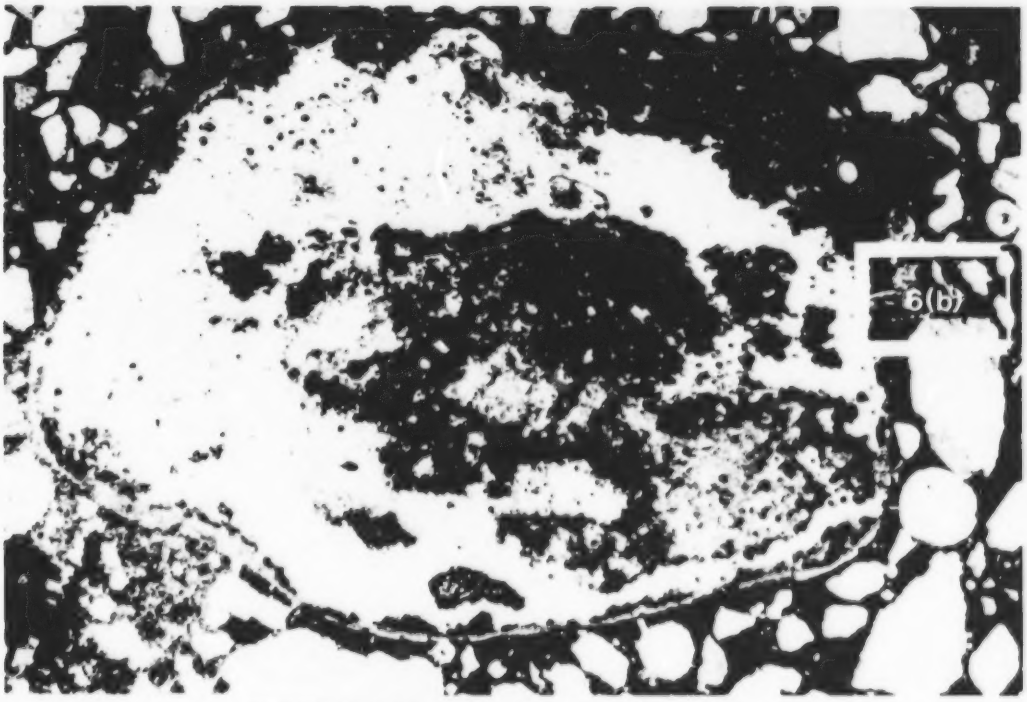


FIGURE 6 (a) - EAR FALLS GS, CORE 6
Gelatinized chert particle partially removed during thin section preparation. The approximate location of Figure 6 (b) is shown.
(Mag. 5.1X, Analyzer out)

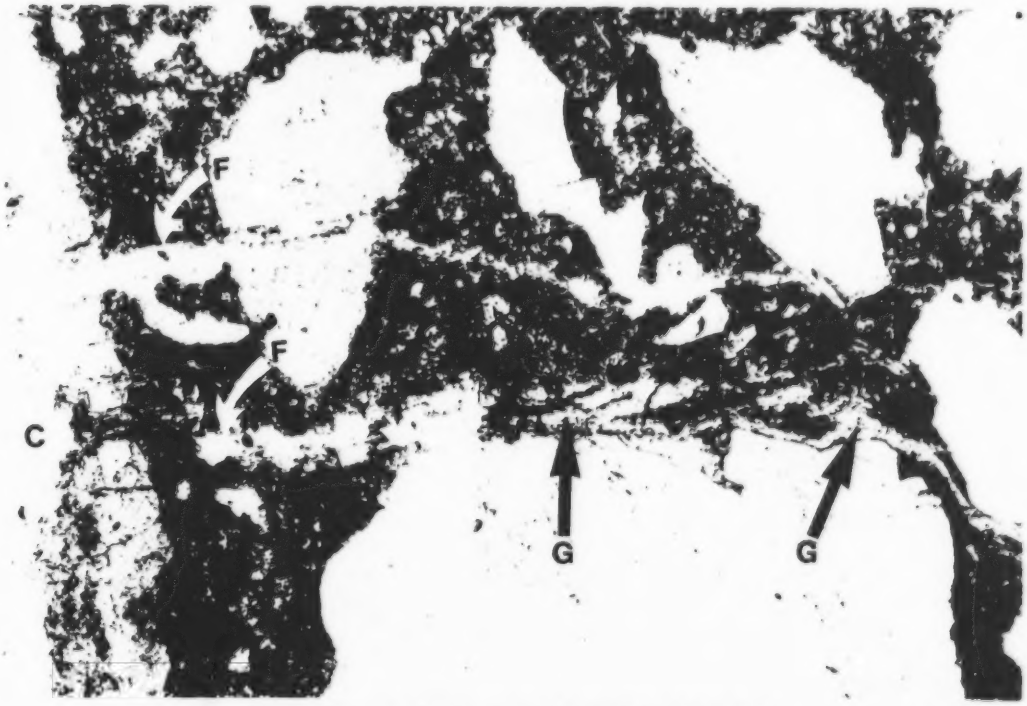


FIGURE 6 (b) - EAR FALLS GS, CORE 6
Microcracks (F) radiating from gelatinized chert particle (C) filled with alkali-silica gel (G).
(Mag. 32X, Analyzer out)

ATTACHMENTS 1 TO 3

Ear Falls GS

Petrographic Examination of Concrete Cores

Attachment 1

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project : Ear Falls GS
Region : Northwestern
Area : Dryden
Structure : Powerhouse, Unit 3

Job No. : 42-115-581
File No. : 842.52 EAR
Report No.: SN89 - 1 - K
Date Issued : June 8, 1989

Sample Type : Core ☑ Cylinder ☐ Chunk ☐

Sample Description : Core EF - 4 , nominal 45 mm diameter . Concrete has undergone approximately 50 years of indoor exposure.

CONCRETE DESCRIPTION :

(1) Total Concrete :

Hit with hammer : Ring ☑ Dull ☐
Break with fingers : Powdery ☐ Friable ☐ Particles not dislodged ☑
During sawing : Clean cut ☑ Breaks easily ☐
Cement / coarse aggregate bond : Good ☑ Poor ☐
Cement / fine aggregate bond : Good ☑ Poor ☐
Presence of honeycombing : Present ☐ Not observed ☑

(2) Coarse Aggregate :

Source : Local bedrock, probably from site excavation.
% of total volume : 45 - 50 %
Material type : Gravel ☐
Shape : Rounded ☐
Distribution : Even ☐
Nominal size : 40 (mm)
Preferred orientation : Present ☐ Not observed ☑

Visual estimate ☑ Point Count ☐
Quarried ☑ Mixture ☐
Partly crushed ☐ 100 % Crushed ☑
Uneven ☑ Chaotic ☐
Other : ☐
Maximum size : 50 (mm)

LITHOLOGICAL TYPES	% OF COARSE AGG.	REACTION RIMS / GEL / FRACTURES	REMARKS
Biotite garnet gneiss	90 - 95	Some particles are fractured. No mineralization associated with fractures.	Migmatites derived from sandstone, chert and limestone.
Other gneisses and volcanics	5 - 10	Same as above	
Chert, argillite and carbonates	< 2	Chert particles are partially or completely gelatinized. Gel extends along fractures into paste.	Some particles of unreactive chalcedony were noted.

(3) Fine Aggregate :

Source : Same as coarse aggregate
% of total volume : 35 - 40 %
Material type : Natural ☐
Shape : Rounded ☐
Distribution : Even ☑
Preferred orientation : Present ☐

Visual estimate ☐ Manufactured ☑ Subrounded ☐ Uneven ☐ Not observed ☑
Point count ☐ Mixture ☑ Subangular ☐ Chaotic ☑
Other : ☐ Angular ☑

(4) Cement Paste:

% of total volume : 10 - 15 % Visual estimate ☑ Point count ☐
Appearance of broken concrete : Subtranslucent ☑ Dull ☐ Chalky ☐
Colour : Grey ☐ Light Grey ☑ White ☐ Brown ☐ Other:
Colour distribution : Even ☑ Mottled ☐ Gradational ☐
Bleeding : Extensive ☐ Minor ☑ Not observed ☐
Carbonation : Surficial only ☑ Along fractures ☐ Partial ☐ Total ☐
Slag cement : Observed ☐ Not observed ☑
Fly ash : Observed ☐ Not observed ☑

(5) Voids:

% of total volume : 3 - 5 % Visual estimate ☑ Point count ☐
Distribution : Even ☐ Uneven ☑ Clustered ☐
Shape : Spherical ☐ Nonspherical ☐ Ellipsoidal ☐ Irregular ☑
Entrained air : Air-entrained ☐ Non air-entrained ☑
Interior lustre : Dull ☑ Shining ☐
Interior condition : Empty ☐ Lined ☐ Partly filled ☑ Totally filled ☐
% Voids with mineralization : Most ☐ About half ☐ Few ☑ None ☐
Mineralization : Alkali-silica gel ☑ Ettringite ☑ Portlandite ☑ Calcium carbonate ☐

(6) Cracks:

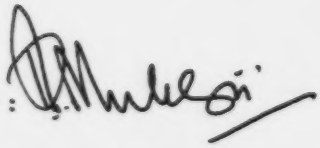
Amount : Extensive ☐ Occassional ☑ None ☐
Continuity and Distribution : Microcracks appear to originate at chert particles and then extend into cement paste.

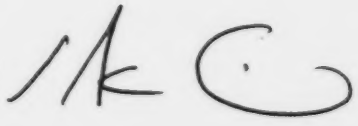
Orientation : Vertical ☐ Horizontal ☐ Random ☑
Location : Through aggregate particles ☑ Around aggregate particles ☑
Width (mm) : Range 0.1 to 0.2 Average : < 0.1 (mm)
% filled : 15 - 20 %
Filling material : Alkali silica gel ☑ Ettringite ☐ Portlandite ☐ Calcium carbonate ☐
Other :
Associated with embedded items : Yes ☐ No ☑

(7) Embedded Items:

Description :
Condition : Clean ☐ Corroded ☐ Decayed ☐
Size (mm) :
Location / Orientation :
Other :

(8) General Comments : Good quality concrete. The only sign of alkai-aggregate reactions is microcracking associated with reactive chert particles.

Approved by : 

Submitted by : 

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ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project : Ear Falls GS
Region : Northwestern
Area : Dryden
Structure : Powerhouse, Unit 4

Job No. : 42-115-581
File No. : 842.52 EAR
Report No.: SN89 - 2 - K
Date Issued : June 8, 1989

Sample Type : Core ☑ Cylinder ☐ Chunk ☐

Sample Description : Core EF - 5, nominal 45 mm diameter. Concrete has undergone approximately 40 years of indoor exposure.

CONCRETE DESCRIPTION :

(1) Total Concrete :

Hit with hammer : Ring ☑ Dull ☐
Break with fingers : Powdery ☐ Friable ☐ Particles not dislodged ☑
During sawing : Clean cut ☑ Breaks easily ☐
Cement / coarse aggregate bond : Good ☑ Poor ☐
Cement / fine aggregate bond : Good ☑ Poor ☐
Presence of honeycombing : Present ☐ Not observed ☑

(2) Coarse Aggregate :

Source : Bergmann Construction Co., Bergmann's Pit, Ear Falls
% of total volume : 50 - 55 % Visual estimate ☑ Point Count ☐
Material type : Gravel ☑ Quarried ☐ Mixture ☑ Other : ☐
Shape : Rounded ☐ Partly crushed ☑ 100 % Crushed ☐
Distribution : Even ☑ Uneven ☐ Chaotic ☐
Nominal size : 28 (mm) Maximum size : 40 (mm)
Preferred orientation : Present ☐ Not observed ☑

LITHOLOGICAL TYPES	% OF COARSE AGG.	REACTION RIMS / GEL / FRACTURES	REMARKS
Granite gneiss	95 - 100	Not observed	
Argillite, greywacke and chert	< 5	Not observed	

(3) Fine Aggregate :

Source : Bergmann's Construction Co., Bergmann's Pit, Ear Falls
% of total volume : 30 - 35 % Visual estimate ☑ Point count ☐
Material type : Natural ☑ Manufactured ☐ Mixture ☐ Other :
Shape : Rounded ☐ Subrounded ☑ Subangular ☐ Angular ☐
Distribution : Even ☑ Uneven ☐ Chaotic ☐
Preferred orientation : Present ☐ Not observed ☑

(4) Cement Paste:

% of total volume : 10 - 15 % Visual estimate ☑ Point count ☐
Appearance of broken concrete : Subtranslucent ☐ Dull ☑ Chalky ☐
Colour : Grey ☐ Light Grey ☑ White ☐ Brown ☐ Other:
Colour distribution : Even ☑ Mottled ☐ Gradational ☐
Bleeding : Extensive ☐ Minor ☐ Not observed ☑
Carbonation : Surficial only ☑ Along fractures ☐ Partial ☐ Total ☐
Slag cement : Observed ☐ Not observed ☑
Fly ash : Observed ☐ Not observed ☑

(5) Voids:

% of total volume : 3 - 5 % Visual estimate ☑ Point count ☐
Distribution : Even ☑ Uneven ☐ Clustered ☐
Shape : Spherical ☐ Nonspherical ☐ Ellipsoidal ☐ Irregular ☑
Entrained air : Air-entrained ☐ Non air-entrained ☑
Interior lustre : Dull ☑ Shining ☐
Interior condition : Empty ☑ Lined ☐ Partly filled ☐ Totally filled ☐
% Voids with mineralization : Most ☐ About half ☐ Few ☐ None ☑
Mineralization : Alkali-silica gel ☐ Ettringite ☐ Portlandite ☐ Calcium carbonate ☐

(6) Cracks:

Amount : Extensive ☐ Occassional ☐ None ☑

Continuity and Distribution :

Orientation : Vertical ☐ Horizontal ☐ Random ☐
Location : Through aggregate particles ☐ Around aggregate particles ☐
Width (mm) : Range to Average
% filled : %
Filling material : Alkali silica gel ☐ Ettringite ☐ Portlandite ☐ Calcium carbonate ☐
Other :
Associated with embedded items : Yes ☐ No ☐

(7) Embedded Items:

Description :
Condition : Clean ☐ Corroded ☐ Decayed ☐
Size (mm) :
Location / Orientation :
Other :

(8) General Comments : Good quality concrete with no signs of alkali-aggregate reactions.

Approved by : [signature]

Submitted by : [signature]

Distribution : Mr. E.J. McColm, Mr. D.G. Wilkinson
Original to Mr. M.F. Everitt, Official Record

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project : Ear Falls GS
Region : Northwestern
Area : Dryden
Structure : Powerhouse, Unit 1

Job No. : 42-115-581
File No. : 842.52 EAR
Report No.: SN89 - 3 - K
Date Issued : June 8, 1989

Sample Type : Core ☑ Cylinder ☐ Chunk ☐

Sample Description : Core EF - 6, nominal 60 mm diameter. Concrete has undergone approximately 60 years of indoor exposure.

CONCRETE DESCRIPTION :

(1) Total Concrete :

Hit with hammer : Ring ☑ Dull ☐
Break with fingers : Powdery ☐ Friable ☐ Particles not dislodged ☑
During sawing : Clean cut ☑ Breaks easily ☐
Cement / coarse aggregate bond : Good ☑ Poor ☐
Cement / fine aggregate bond : Good ☑ Poor ☐
Presence of honeycombing : Present ☐ Not observed ☑

(2) Coarse Aggregate :

Source : Local bedrock, probably from site excavation.
% of total volume : 45 - 50 %
Material type : Gravel ☐ Quarried ☑
Shape : Rounded ☐ Partly crushed ☐
Distribution : Even ☐ Uneven ☑
Visual estimate ☑ Point Count ☐
Mixture ☑ Other : ☐
100 % Crushed ☑
Chaotic ☐
Nominal size : 40 (mm) Maximum size : 50 (mm)
Preferred orientation : Present ☐ Not observed ☑

LITHOLOGICAL TYPES	% OF COARSE AGG.	REACTION RIMS / GEL / FRACTURES	REMARKS
Biotite garnet gneiss	90 - 95	Some particles are fractured. No mineralization associated with fractures.	Migmatites derived from sandstone, chert and limestone.
Other gneisses and volcanics	5 - 10	Same as above	
Chert, argillite and carbonates	< 2	Chert particles are partially or completely gelatinized. Gel extends along fractures into paste.	

(3) Fine Aggregate :

Source : Same as coarse aggregate.
% of total volume : 35 - 40 %
Material type : Natural ☐ Manufactured ☑
Shape : Rounded ☐ Subrounded ☐
Distribution : Even ☐ Uneven ☑
Preferred orientation : Present ☑ Not observed ☐
Visual estimate ☑ Point count ☐
Mixture ☑ Other : ☐
Subangular ☐ Angular ☑
Chaotic ☑

(4) Cement Paste:

% of total volume : 10 - 15 % Visual estimate ☑ Point count ☐
Appearance of broken concrete : Subtranslucent ☐ Dull ☑ Chalky ☐
Colour : Grey ☐ Light Grey ☑ White ☐ Brown ☐ Other:
Colour distribution : Even ☑ Mottled ☐ Gradational ☐
Bleeding : Extensive ☐ Minor ☑ Not observed ☐
Carbonation : Surficial only ☑ Along fractures ☐ Partial ☐ Total ☐
Slag cement : Observed ☐ Not observed ☑
Fly ash : Observed ☐ Not observed ☑

(5) Voids:

% of total volume : 3 - 5 % Visual estimate ☑ Point count ☐
Distribution : Even ☐ Uneven ☑ Clustered ☐
Shape : Spherical ☐ Nonspherical ☐ Ellipsoidal ☐ Irregular ☑
Entrained air : Air-entrained ☐ Non air-entrained ☑
Interior lustre : Dull ☑ Shining ☐
Interior condition : Empty ☐ Lined ☑ Partly filled ☑ Totally filled ☐
% Voids with mineralization : Most ☐ About half ☐ Few ☑ None ☐
Mineralization : Alkali-silica gel ☑ Ettringite ☑ Portlandite ☐ Calcium carbonate ☐

(6) Cracks:

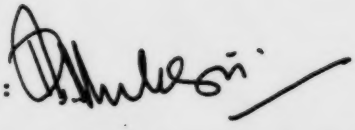
Amount : Extensive ☐ Occassional ☑ None ☐
Continuity and Distribution :

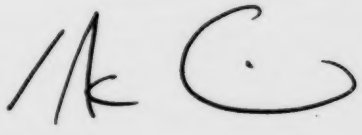
Orientation : Vertical ☐ Horizontal ☐ Random ☑
Location : Through aggregate particles ☑ Around aggregate particles ☑
Width (mm) : Range 0.1 to 0.2 Average : < 0.1 (mm)
% filled : 20 - 25 %
Filling material : Alkali silica gel ☑ Ettringite ☐ Portlandite ☐ Calcium carbonate ☐
Other :
Associated with embedded items : Yes ☐ No ☑

(7) Embedded Items:

Description :
Condition : Clean ☐ Corroded ☐ Decayed ☐
Size (mm) :
Location / Orientation :
Other :

(8) General Comments : Good quality concrete. The only signs of deterioration due to alkali-aggregate reactions is microcracking associated with chert particles.

Approved by : 

Submitted by : 

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